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Method and Apparatus for Fast Handoff in a Communication System

Field of the Invention

The present invention relates to communication systems, in particular, a code division multiple access communication system.

Background of the Invention

Handoff of a communication link from a first communication resource to a second resource is well known in the field of communication systems. There may be various types of handoff with various degrees of differences in operation and effects on the overall system processing capacity and performance. Hard handoff method, for example, involves transition between disjoint sets of base stations, different band of frequency assignments, different band of classes, or different frame offsets. Soft handoff normally involves transition from a first communication resource to a second one without disruption of the communication services, which may involve transition between different channels within the same frequency assignment.

Referring to FIG. 1, a communication system network 100 comprising of cells 110, 120 and 130 is shown where each cell has a sector arrangement. A communication network may have more or less number of cells or sectors. Cells 110, 120 and 130 each is shown to have six sectors, sectors 111-16, 121-26 and 131-36 respectively. Each cell is shown to have

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an associated base station transceiver (BTS), such as BTSs 160, 170 and 180 for respectively cells 110, 120 and 130. Each sector of a cell may have independent hardware and software resources in a BTS associated with the cell. Such resources may include directional antenna for each sector, amplifier, controller and controlling software. Resources for each sector is shown by way of segmenting each cell resources into segments 160-i through j, 170-i through j, and 180-i through j. A central base station controller (CBSC) 190 is shown to communicate with every BTS for overall control and operation of the network 100. Such control includes management of mobile stations communicating with the network 100 through various BTS resources. Such communication may be through backhaul connections 162, 172 and 182 for respectively BTS 160, 170 and 180.

In code division multiple access (CDMA) communication system, a network, such as network 100, may be assigned to one frequency channel. A CDMA system includes a coding scheme that allows multiple users to operate and communicate on different carrier signals all having the same frequency channels. The network may further include pilot signals. Each pilot signal may be coded according to a unique code, thus distinguishing the pilot signals. Normally, each sector has an assigned pilot signal. All mobile stations to communicate with a sector and obtain channel estimates may use the pilot signal from the sector; there may be other uses of the

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pilot signal. A set of communication channels, all having a common frequency assignment, normally is associated with a pilot signal. When a mobile station detects a pilot signal from a sector with sufficient strength, the mobile station reports the signal strength to a BTS. Such a BTS is
5 normally associated with the cell that incorporates the sector which originated the pilot signal. The BTS then assigns a forward traffic channel (FWC) on the same sector to the mobile station and directs the mobile station for other tasks. Other task may include soft handoff from the first assigned sector to another.

10 A mobile station in a CDMA system searches for pilot signals to detect presence of an available communication channel by making signal strength measurement of the pilot signals. The signal strength and interference levels in combination may be compared against a threshold before accepting presence of an available communication channel. The
15 mobile station monitors pilot signal level received from neighboring sectors and cells and reports to the network which pilot signal crossed a set of predefined or dynamic thresholds. One of the sectors may be defined as the dominant sector and others around the dominant sector as the neighboring sectors. Normally, the mobile station identifies the
20 dominant sector as the sector with strongest pilot signal or the sector that its transmitted traffic channel signal was received most strongly at the mobile station. Based on this report, the network orders the mobile station

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to add or remove channels from a list of channels commonly called an active set.

The information, targeted for a mobile station, modulated by appropriate code is sent from multiple sectors identified in the active set to the mobile station. The mobile station may then use the signals sent from the multiple sectors identified in the active set in a Rake receiver diversity combining method to improve its reception. The multiple sectors may be from a sector arrangement of the same cell or different cells. The active set contains identity of a set of sectors that are transmitting to the mobile station. Such identification may be in the form of identifying the pilot signals associated with the sectors. This method of adding and dropping channels from the active set for diversity combining is commonly referred to as soft handoff. When at least some of the multiple sectors in the handoff are from different sector of a common cell, the method of adding and dropping channels in the active set is commonly referred to as softer handoff.

The signal transmitted from a mobile station may be received and processed by the sectors that are included in the mobile station active set. The signals received at different sector may be combined to improve reception. For example, a mobile station 195 is shown to be in a three-way handoff in network 100. Signals 197 and 198 are associated respectively with sectors 134 and 135 of cell 130, and signal 196 is associated with

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sector 115 of cell 110. Each signal is shown to be bi-directional. The mobile station 195 may combine all three signals, 196, 197 and 198 transmitted from the base stations to improve forward link reception. The CBSC 190 may instruct BTSs 160 and 180 to combine the received signals 196, 197 and 198 to improve reverse link reception. On the forward link, sectors in the soft or softer handoff each transmit a signal targeted for the mobile station. On the reverse link, the mobile station may transmit only one signal to be received possibly by all sectors involved in the handoff. The CBSC 190 involves all BTSs associated with each sector in the active set through backhaul connections 162, 172 and 182 to execute soft or softer handoff.

While soft handoff or softer handoff improves an overall performance of the system, in some situation it may negatively impact system capacity and resources. For example, multiple softer handoff routines may burden the overall network backhual capacity by requiring each sector, through an associated BTS, to communicate with the CBSC 190 more often than it may be necessary, in addition of increasing processing load of the CBSC 190. Moreover, in case of a dispatch, for example, the speed of the dispatch is negatively impacted.

Therefore, there is a need for a method and apparatus that provides advantages of handoffs in a communication system without its negative impact.

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Brief Description of the Drawings

FIG. 1 depicts a communication network cell and sector arrangements.

5 FIG. 2 depicts a call flow according to prior art.

FIG. 3 depicts a communication flow according to prior art.

FIG. 4 depicts a communication call flow according to various aspects of the invention.

10 FIG. 5 depicts a communication call flow according to various aspects of the invention.

FIG. 6 depicts a block diagram of a communication system according to various aspects of the invention.

Detailed Description of the Preferred Embodiment(s)

15 In one or more aspects of the invention, a communication system assigns to a mobile station at least a forward communication channel from each sector of a cell. The communication system may have one or more cells to provide communication services to a number of mobile stations in a coverage area. Each cell may have several sectors. Each sector may
20 independently provide the communication services. The communication system assigns at each sector orthogonal spreading codes to the assigned channels. Assigning codes to each channel successfully ensures that each channel is ready to be used once a signal is transmitted with adequate

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transmit gain. According to the invention, the communication system adjusts a transmit gain of at least one of the assigned channels to zero transmit gain, or a very low transmit gain. The adjustment may take place at the sector. The mobile station places each sector of the cell that has at least one assigned channel in an active channel set. The mobile station normally combines the strongest signal paths in terms of pilot strength or pilot signal to signal plus interference ratio (E_c/I_o) taken from its active set; however, according to the invention, the mobile station does not always combine a signal path of a channel in its active set that has a zero transmit gain, or a very low transmit gain, set at its transmitting sector even in the case where its pilot E_c/I_o is above lock and combining thresholds. The mobile station, however, normally reports at least one pilot E_c/I_o of pilot signals transmitted from each sector of the cell. The communication system compares the reported pilot signal E_c/I_o to a threshold. The communication system furthermore selects, based on the comparison, at least one of the channels for adjusting its transmit gain to zero transmit gain or a very low transmit gain. The mobile station continues to report E_c/I_o information of pilot signals measured at the mobile station. The communication system compares the newly reported E_c/I_o of the pilot signals transmitted from each sector of the cell to at least one of a threshold-add and a threshold-compare. Based on the result of the comparison, the communication system changes transmit gain of at least

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one of the channels with a transmit gain adjusted to zero (or low) transmit gain from zero (or low) transmit gain to a forward power control gain setting of forward communication channels.

One or more aspects of the invention may be more apparent by making references to communication call flows shown in FIGs. 2, 3, 4 and 5. A call flow 200 shown in FIG. 2 is according to the prior art. Call flow 200 may be a call flow between a mobile station and a base station to establish a call connection. A call flow 300 shown in FIG. 3 is according to prior art. Call flow 300 may be a call flow to perform softer handoff between a mobile station and a base station after establishing a call connection.

Referring to FIG. 2, to make a call connection from a base station to a mobile station, for example, a BTS sends a page message 211 to a mobile station. The mobile station reports back on an access message 212 Ec/Io and Pseudo Code (PN) offset value of pilot signals measured at the mobile station. The pilot signals were transmitted from different sectors in the communication system. Such information indicates to the base station whether the mobile station is located in an area that can adequately be provided with communication services, and if such a condition exist, which BTS (i.e. which sector) may most effectively provide such services. The base station controller (BSC), which may be a centralized BSC, after receiving through a message 213 the information contained in message

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212, selects one or more BTSs to serve the mobile station. Such a selection may be based on comparing E_c/I_o and PN offset information to one or more thresholds. The BSC communicates the channel assignments to the serving BTSs through a channel assignment message 214 which includes
5 the orthogonal spreading codes or Walsh codes to use for each forward channel. There may be more than one sector (BTS) that can provide the communication service. Each selected BTS would transmit the information targeted for the mobile station. Each selected BTS assigns orthogonal spreading codes, such as Walsh code, to each forward link and begins to
10 transmit on those forward channels to the mobile station. At about the same time, each BTS communicates that information to the BSC via a forward channel transmit indication message 216. The BSC subsequently sends a message to mobile station informing the mobile station that one or more channels have been assigned for the mobile station along with their
15 corresponding Walsh code and pilot PN offset via channel assignment message 217. The mobile station places the assigned channels in its active channel set list. The mobile station, in such situation, combines the top n strongest signals (in terms of pilot E_c/I_o) transmitted from all sectors that the base station has identified for the mobile station.

20 Referring to FIG. 3, call flow 300 shows a call flow between a mobile station and the base station for performing softer handoff. The mobile station, normally, searches for pilot signals transmitted from

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different sectors for measuring their E_c/I_o and PN offset value. The mobile station transmits such information to the BSC via a Pilot Strength Mobile Measurement (PSMM) 311; in return, BSC acknowledge such information via ACK message 312. If the reported E_c/I_o meets a threshold level, BSC sends a Channel Assignment message 313 to the BTS responsible for transmission of that pilot signal to assign an orthogonal spreading code to a newly assigned channel for the mobile station. Each selected BTS assigns orthogonal spreading codes, such as Walsh code, to each newly assigned forward channel and begins to transmit on those forward channels to the mobile station. The BTS indicates via a message 315 to BSC that transmission has begun on the new forward channel. BSC in response sends a handoff direction message 316 to the mobile station directing the mobile station to include the newly assigned channel in the active channel set of the mobile station for softer combining operation along with the Walsh code and pilot PN offset.

Referring to FIG 4, one or more aspects of the invention are shown by way of a call flow 300. Messages 211, 212 and 213 may be performed according to prior art. According to the invention, when BSC decided to assign a channel at a sector of a cell to the mobile station, BSC assigns at least one channel from each sector in the cell of the communication system. For example, if E_c/I_o of a sector of a cell was acceptable (i.e. above a threshold,) the BSC assigns a channel from every sector of the cell that

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has at least one acceptable E_c/I_o . In connection, the reverse link Rake receiver finger energy may be measured to determine if a mobile station is communicating on a channel at a sector. The communication system, in turn, assigns other channels at other sectors of the same cell to the mobile station; however, their transmit gain is set to zero or very low transmit gain. Such messaging between BSC and BTS is shown by way of message 410. The BTS then assigns orthogonal spreading codes to each assigned channel, and begins to transmit on each channel using a gain equal to the power control gain or to zero or a low value based on E_c/I_o information obtained from the access message and based on the reverse link Rake receiver finger energy from each sector. A forward transmit indication message 216 is sent to BSC from BTS. In response, BSC transmits message 217 to the mobile station regarding channel assignments which include the assigned orthogonal spreading codes and the pilot PN offsets used via message 217. In connection, BTS internally sets the transmit gain of certain channels in the channel assignments to zero (or very low) transmit gain via an internal control message 420, and optionally informs the mobile station, via a message 430, thus, preventing the mobile station from assigning a demodulator finger to the channels that have zero (or very low) transmit gain. Alternatively instead of message 430 the mobile can determine the signal to noise ratio of the data signal to determine when not to combine the signal even when the corresponding pilot E_c/I_o can be

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detected. According to the invention, BSC assigns more channels to the mobile station even though E_c/I_o of some of the channels either did not satisfy the threshold or were not received at all. The BSC assigns at least a channel from each sector of a cell that has at least one sector with acceptable E_c/I_o . BTS, in connection, assigns orthogonal codes to all assigned channels, few of which would have zero (or very low) transmit gain.

Referring to FIG. 5, a call flow 500 is shown to reduce the number of communication between BTS and BSC for performing a softer handoff direction for a mobile station mainly due to call flow 400 shown in FIG. 4. Reduction of messaging between BTS and BSC allows reduction of the backhual communication. Such reduction improves efficiency of backhual resources. According to the invention, mobile station transmits PSMM message 510 to BTS, and BTS directly acknowledges PSMM information via message 520 with the mobile station. The PSMM information are compared to Threshold-Add and Threshold_Comp to decide whether one of the assigned channels with zero (or very low) transmit gain should change its transmit gain to forward channel gain value. The decision to use zero (or very low) transmit gain may also be based on the reverse link finger energy for a given sector which is zero (or very low) if there is no finger assigned in that sector. The mobile station accordingly assigns a finger to the newly added channel, and combines the channel with other

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channel in a softer handoff operation. As such, messaging between the BSC and BTS has been eliminated or substantially reduced.

One or more aspects of the invention may be more apparent in block diagram 600 shown in FIG. 6. Block diagram 600 is a conceptual
5 block diagram of various blocks in a communication system supporting operation of a cell that has three sectors. A sector sums its traffic, control and overhead channels in block 670, 680, or 690. The summed signal passes to a modulator, such as modulator 671, 681 or 691 before being transmitted on appropriate frequency via an antenna, such as antenna 672,
10 682, or 692. The communication system through its control channels or otherwise communicates with the mobile station via blocks 670, 680 or 690 regarding the identification of the sectors that are needed to be included in the mobile station active channel list. The mobile station may incorporate a memory element to store the list for its use. Moreover, through the same
15 means, the communication system communicates with the mobile station that certain of the channels in the active list should not be involved in a softer combining operation. This last step is optional especially if the mobile station bases combining partly on whether the data signal (instead of pilot signal) has energy exceeding some combining threshold.

20 The information to be transmitted to a mobile station from a sector is received at input 610 of a transmit block 601. Transmit block 601 may include a channel multiplexer 611, a convolutional encoder 612, a symbol

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repeater 613, a block interleaver 614 and a long code scrambler 615. The transmit information pass through blocks 611-15 to produce encoded transmit information 616. A coder 651 adds encoded information 616 to an assigned Walsh code 617 to produce a code multiplexed information 656.

5 According to the invention, encoded information 616 pass to all other coders at other sectors, such as coders 652 and 653, to be code multiplexed via a code adding operation with other Walsh codes, such as Walsh codes 618 and 619. The code multiplexed information 657 and 658 are produced as a result. Walsh codes 617, 618 and 619 are assigned to the user of the

10 information at each sector.

The gain adjuster 620 adjusts the gain of code multiplexed information 656 according to an output 699 via an output 641. For adjusting gain of code multiplexed information 657 and 658, a gain switch 698 adjusts the gain to either zero (or very low) transmit gain or gain

15 according to output 699 via outputs 642 and 643. The selection is based on whether pilot E_c/I_o of the sector measured by mobile station, provided at input 696, of the user has satisfied threshold-add or threshold-comp. If either threshold is satisfied, the transmit gain adjust is according to output 699; otherwise, the transmit gain is equal to a zero (or very low) transmit

20 gain value 697. Additionally, the selection may be based on whether the base station has measured energy on a Rake finger receiver applied to the reverse link of the sector. If the energy is attributed to a signal transmitted

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from the mobile station, the transmit-gain is adjusted according to output 699. The transmit gain output 699 is based on information, for example 661 power control bit information and signal quality information 662, received by the system at a gain computer 660. After gain adjustments, signals 663, 5 664 and 665 are produced.

Correspondingly at each sector, the signals 663, 664 and 665 are inputs to transmit blocks 666, 667 and 668 where they are scrambled by a pair of pseudo-random codes to produce appropriate transmit signals for combining operation in summing blocks 670, 682 and 692. According to 10 the invention, if code multiplexed information 657 and 658 are to be involved in a softer combining operation the mobile station, one or two commands communicated between the mobile station and the base station completes the operation. Such completion may be via changing the transmit gain of the signals involved in the softer combine operation from 15 zero (or very low) gain to a transmit gain according to output 699. Such a change is accomplished by simply changing a data bit in gain switch 698. As a result, a substantial reduction of control and communication between the involved blocks is achieved. This in turn reduces the backhaul communication traffic.

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Claims

1. A method in a communication system comprising the steps of:
- 5 (a) assigning to a mobile station at least a forward communication channel from each sector of a cell in said communication system;
- (b) assigning orthogonal spreading codes to said least assigned channels in said step (a);
- 10 (c) adjusting a transmit gain of at least one of said channels assigned in said step (a) to zero or very low gain;
- (d) placing each sector of said cell that has at least one assigned channel in step (a) in an active channel set at said mobile station.
- 15
2. The method as recited in claim 1 further comprising the steps of:
- (e) reporting at least one pilot E_c/I_o of pilot signals transmitted from each sector of said cell;
- 20 (f) comparing said reported pilot signal E_c/I_o to a threshold;

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- (g) selecting, based on said comparing at said step (f), said least one of said channels for said adjusting said transmit gain to zero or very low gain at said step (c).

5 3. The method as recited in claim 1 further comprising the steps of:

- (h) preventing said mobile station from combining signals from channels in said active set that has an associated transmit gain set to zero or very low at each sector at said step (c).

10

 4. The method as recited in claim 1 further comprising the steps of:

- (i) comparing E_c/I_o of pilot signals transmitted from each sector of said cell to at least one of a threshold-add and threshold-compare;

15

- (j) reporting a result of said comparing at step (i) to said cell;
- (k) changing, based on said reported result, transmit gain of at least one of said channels adjusted to zero or very low gain from zero or very low gain to forward power control gain setting of forward communication channels.

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5. The method as recited in claim 1 further comprising the steps of:

(l) measuring a Rake receiver finger energy level, wherein said Rake receiver is at one sector of said cell;

5 (m) comparing said measured Rake receiver finger energy to a threshold;

(n) selecting, based on said comparing at said step (m), said least one of said channels for said adjusting said transmit gain to zero or very low gain at said step (c).

10

6. An apparatus in a communication system comprising:

(a) means for assigning to a mobile station at least a forward communication channel from each sector of a cell in said communication system;

15 (b) means for assigning orthogonal spreading codes to said least assigned channels in said step (a);

(c) means for adjusting a transmit gain of at least one of said channels assigned in said step (a) to zero or very low gain;

(d) means for placing each sector of said cell that has at least one
20 assigned channel in step (a) in an active channel set at said mobile station.

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7. The apparatus of claim 6 comprising:

- (e) means for reporting at least one pilot E_c/I_o of pilot signals transmitted from each sector of said cell;
- (f) means for comparing said reported pilot signal E_c/I_o to a threshold;
- (g) means for selecting, based on said comparing at said step (f), said least one of said channels for said adjusting said transmit gain to zero or very low gain at said step (c).

8. The apparatus of claim 6 comprising:

- (h) means for preventing said mobile station from combining signals from channels in said active set that has an associated transmit gain set to zero or very low at each sector at said step (c).

9. The apparatus of claim 6 comprising:

- (i) means for comparing E_c/I_o of pilot signals transmitted from each sector of said cell to at least one of a threshold-add and threshold-compare;
- (j) means for reporting a result of said comparing at step (i) to said cell;

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- (k) means for changing, based on said reported result, transmit gain of at least one of said channels adjusted to zero or very low gain from zero or very low gain to forward power control gain setting of forward communication channels.

5

10. The apparatus of claim 6 comprising:

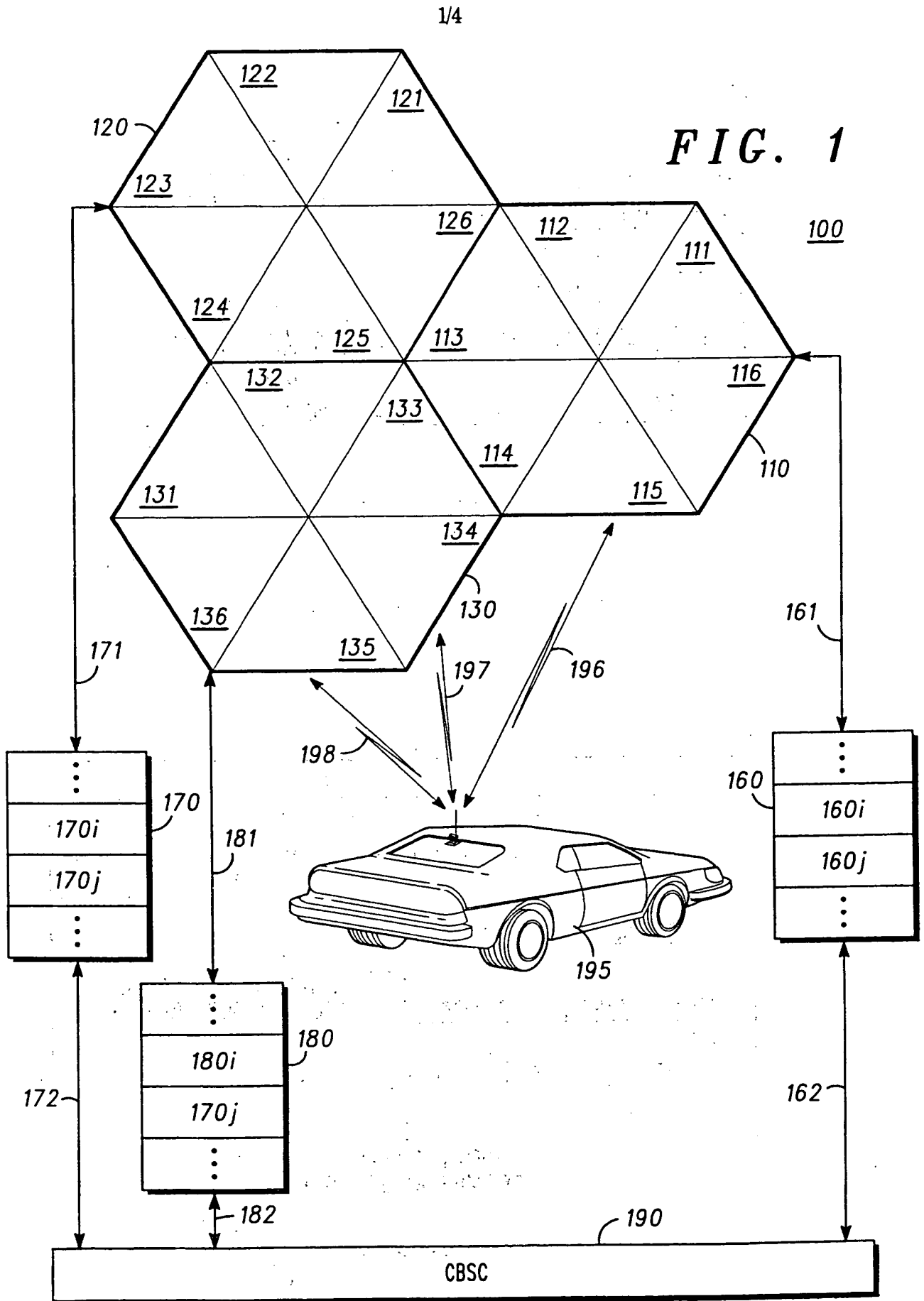
- (l) means for measuring a Rake receiver finger energy level, wherein said Rake receiver is at one sector of said cell;

- (m) means for comparing said measured Rake receiver finger energy to a threshold;

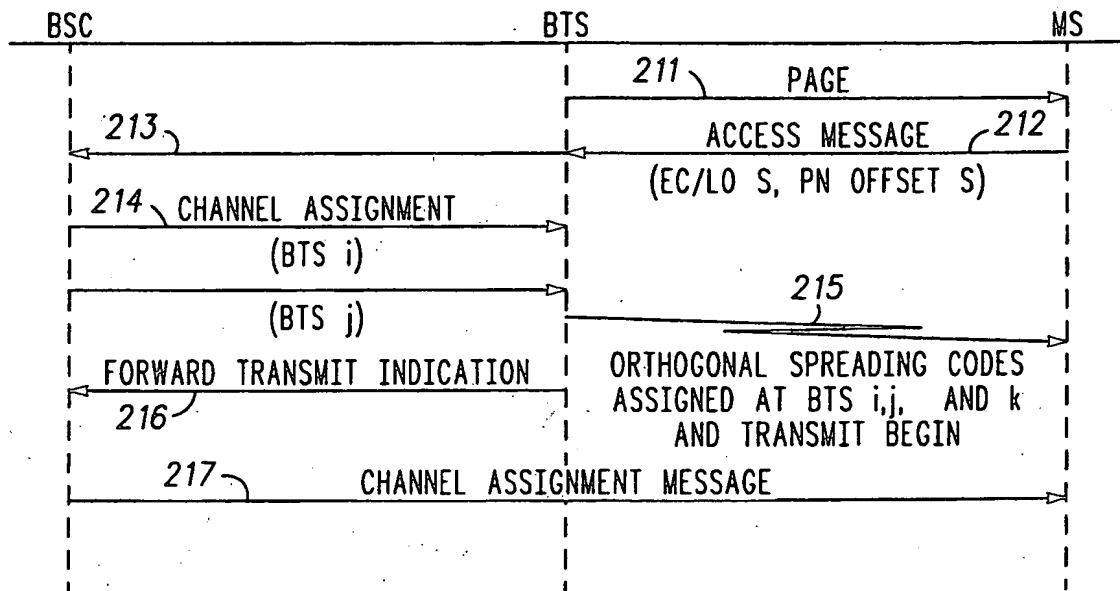
10

- (n) means for selecting, based on said comparing at said step (m), said least one of said channels for said adjusting said transmit gain to zero or very low gain at said step (c).

15

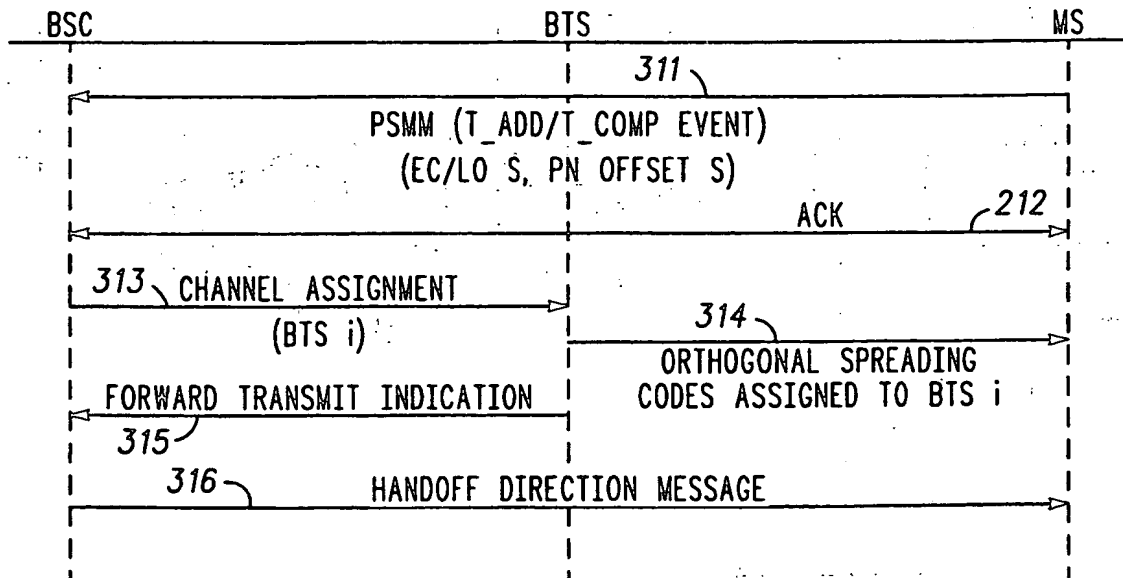


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NORMAL FORWARD PC
CONTINUES AT BTS'S OR BSC

-PRIOR ART-

FIG. 2 200

NORMAL FORWARD PC
CONTINUES AT BTS OR BSC

-PRIOR ART-

300

FIG. 3

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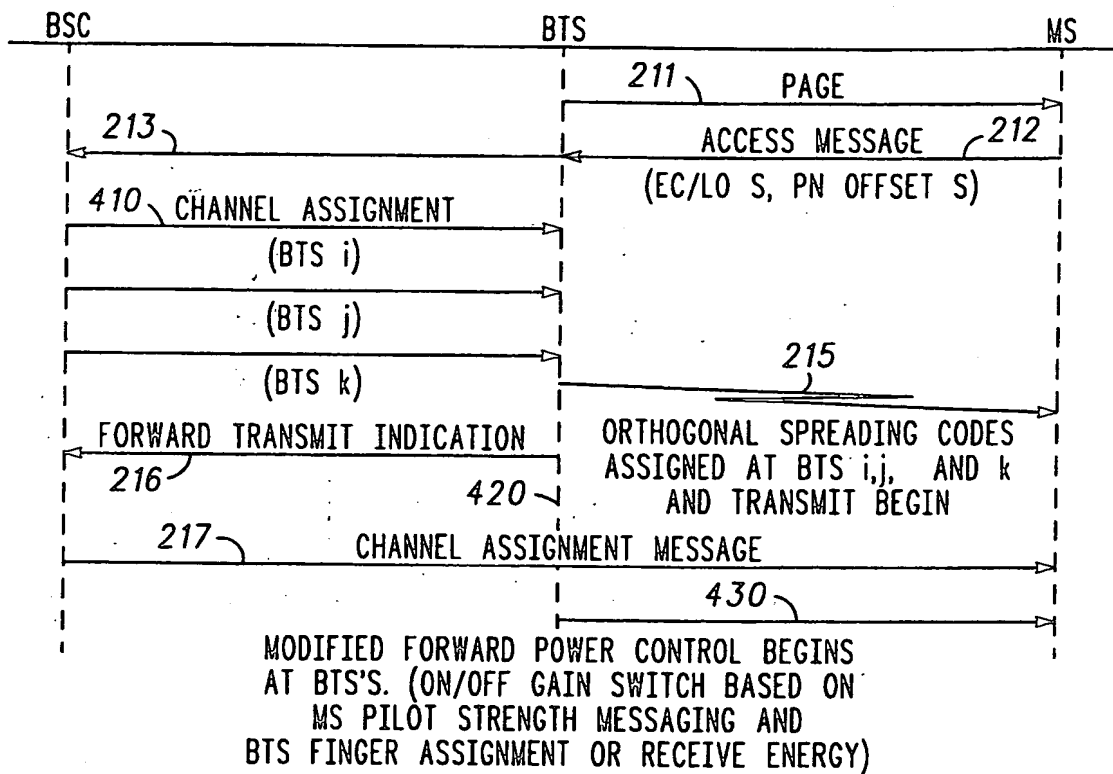


FIG. 4

400

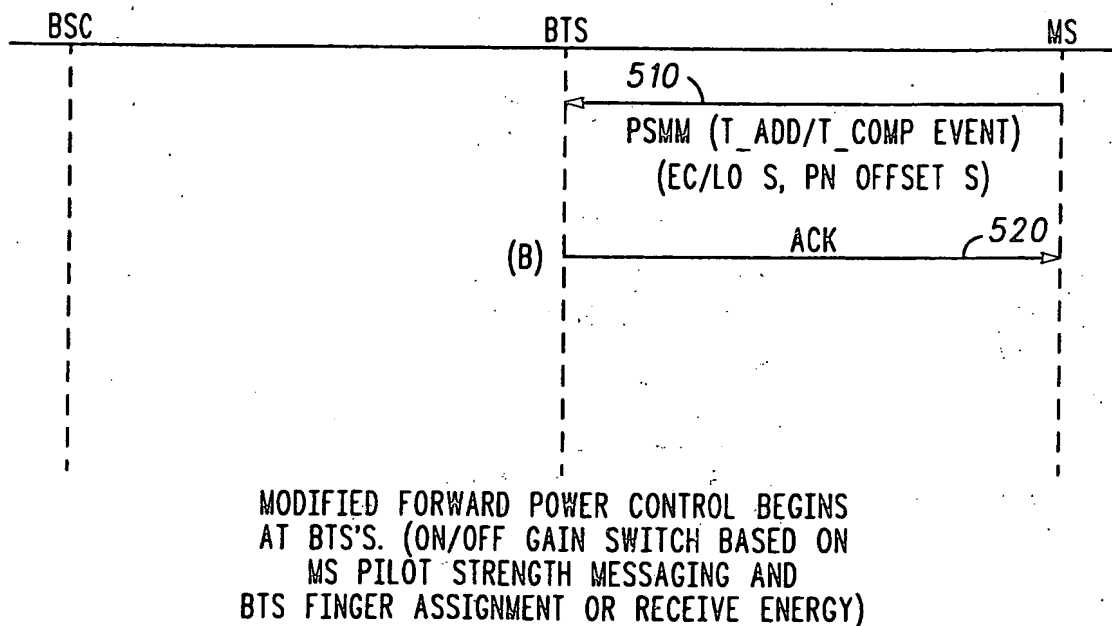


FIG. 5

500

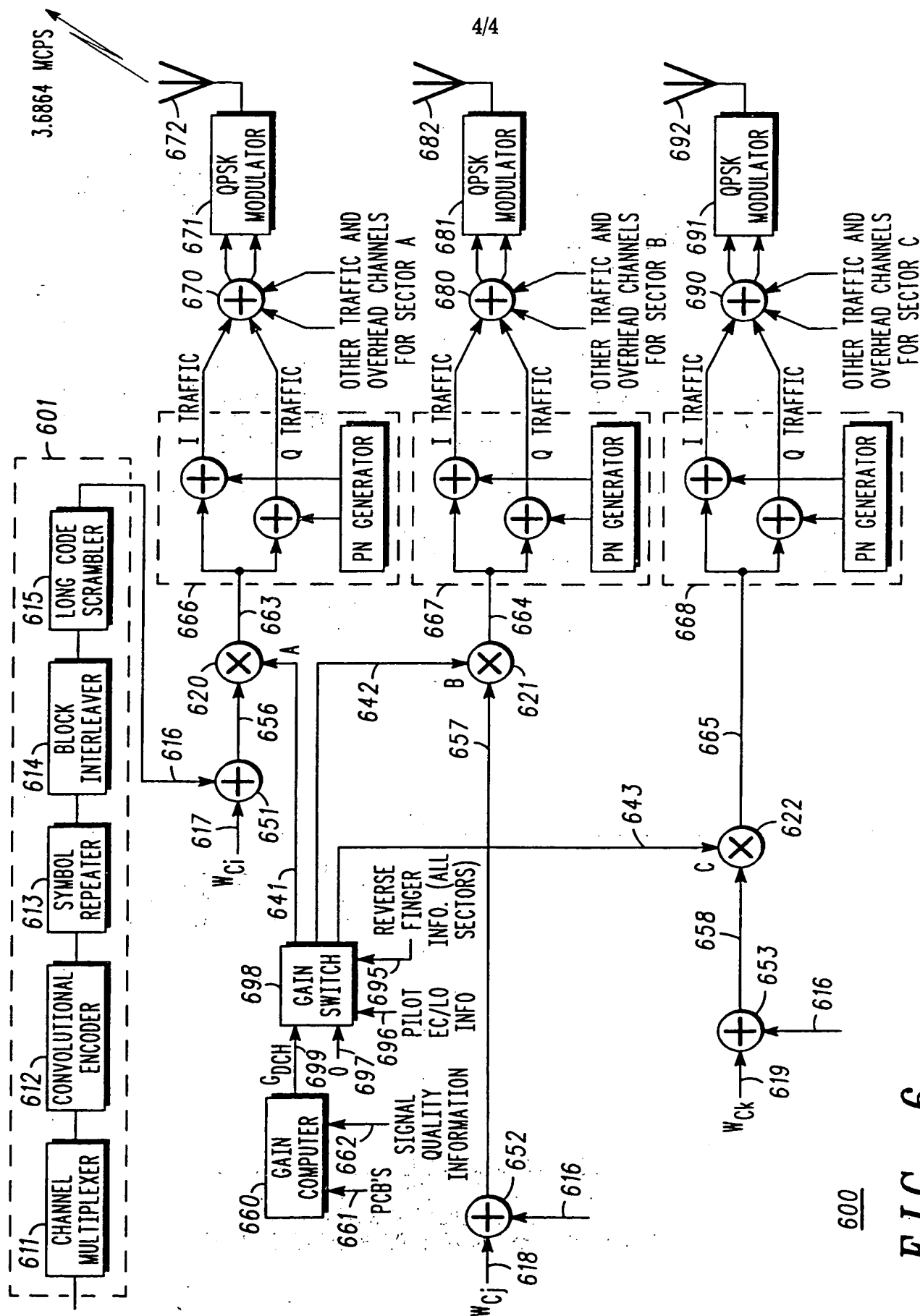


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/11436

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H04Q 7/00, 7/20

US CL : 370/332; 455/437, 442

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/320, 332, 328-332, 335, 342, 479; 455/436-439, 442

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

East

search terms: handoff, CDMA, soft handoff, active set

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim
X	US 5,548,808 A (BRUCKERT et al.) 20 August 1996, Figures 1 and 3-5	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

A	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	*T*	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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L	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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P	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

02 JULY 2000

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